PTO 09-2001

CC=JP
DATE=19930928
KIND=KOKAI
PN=052429320

PLANAR ILLUMINATION OPTICAL WAVEGUIDE DEVICE
[MENSHOMEIYO HIKARIDOUHA SOCHI]

FURUKAWA, MASAAKI, ET AL.

UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, D.C. JANUARY 2009
TRANSLATED BY: SCHREIBER TRANSLATION, INC.

PUBLICATION COUNTRY	(10):	JP
DOCUMENT NUMBER	(11):	052429320
DOCUMENT KIND	(12):	KOKAI
PUBLICATION DATE	(43):	19930928
APPLICATION NUMBER	(21):	4-82787
APPLICATION DATE	(22):	19920304
INTERNATIONAL CLASSIFICATION	(51):	G02B 6/00 GO2F 1/1335 G09F 13/04
PRIORITY COUNTRY	(33):	N/A
PRIORITY NUMBER	(31):	N/A
PRIORITY DATE	(32):	N/A
INVENTOR(S)	(72):	FURUKAWA, MASAAKI; HASHIMOTO, NOBORU; AND IMOTO, HIROTAKE
APPLICANT(S)	(71):	NISSIN HIGH-TECH CO., LTD. TECHNO SYSTEM CO., LTD.
DESIGNATED CONTRACTING STATES	(81):	N/A
TITLE	(54):	PLANAR ILLUMINATION OPTICAL WAVEGUIDE DEVICE
FOREIGN TITLE	[54A]:	MENSHOMEIYO HIKARIDOUHA SOCHI

/2[1]

[What is Claimed is:]

[Claim 1]

A planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity are obliquely placed in a symmetrical manner so as to create a V-formation; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X (N_1 > N_2 > . . . N_K >> N_L)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body; end faces of light incidence layers, which are the inner ends of said plate-like optical waveguide layers placed symmetrically within said optical transmission body, are continuously arranged from the inner bottom ends of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the

[1] Numbers in the margin display pagination in the foreign text.

outer ends of said symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; and a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face.

[Claim 2]

A planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity are obliquely placed in a symmetrical manner so as to create a V-formation; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X (N_1 > N_2 > . . . N_K >> N_L)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body; end faces of light incidence layers, which are the inner ends of said plate-like optical waveguide layers placed in a

symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of said symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; a light diffusion layer with refractive index N_R, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face; and said plate-like optical waveguide layers conduct multimode light transmission and the minimum relative refractive index difference $\{\Delta_1 = [(N_K - N_1)/N_K] \times 100\ \%\}$ of said plate-like optical waveguide layers is 1 % or more.

[Claim 3]

A planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity are obliquely placed in a symmetrical manner so as to create a V-formation; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X ($N_1 > N_2 > . . . N_K >> N_L$)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body; end faces of light incidence layers, which are the inner ends of said plate-like optical waveguide layers placed in a symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of the symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said symmetrically-placed low refractive index layers or high

reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face; and a liquid crystal panel is created on the top surface of said light diffusion layer.

[Claim 4]

A planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity are obliquely placed in a symmetrical manner so as to create a V-formation; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X (N_1 > N_2 > . . . N_K >> N_L)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body; end faces of light incidence layers, which are the inner ends of said plate-like optical waveguide layers placed in a symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of

said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of said symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face; and a light reflective body is created below the light source, which is placed in said light source space.

[Claim 5]

The planar illumination optical waveguide device as set forth in claims 1 to 4, wherein the light incidence end faces of the optical transmission body are made from a surface, which slopes in the outward direction by a desired

angle relative to the perpendicular of the light exit end face.

[Claim 6]

The planar illumination optical waveguide device as set forth in claims 1 to 4, wherein the light incidence end faces of the optical transmission body are curved and concave to the light source.

[Claim 7]

The planar illumination optical waveguide device as set forth in claims 1 to 4, wherein the surfaces of the low refractive index layers or high reflectivity layers are flat or curved.

[Claim 8]

The planar illumination optical waveguide device as set forth in claims 1 to 4, wherein the thickness of the plate-like optical waveguide layers of the optical transmission body is uniform or tapered off along the direction of light propagation.

/3

[Claim 9]

A planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity, which are made from horizontal parts and sloped parts connected to said

horizontal parts, are obliquely placed in a symmetrical manner so as to create hook-like V-formations; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X ($N_1 > N_2 > . . . N_K >> N_L$)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body and said plate-like optical waveguide layers are made from laterally-facing layer parts and sloped layer parts, which are created together with said horizontal parts and sloped parts of said low refractive index layers or high reflectivity layers; end faces of light incidence layers, which are the inner ends of said laterally-facing layer parts of said plate-like optical waveguide layers placed in a symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of said horizontal parts of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of said sloped layer parts of said symmetrically-

placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said sloped parts of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; and a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an improved planar illumination optical waveguide device, which is used in a variety of types of planar illumination device for signs, liquid crystal display back lights and the like and can equalize brightness within the surface and maintain high brightness.

[0002]

[Prior Arts]

Recently, due to the widespread use of variety of types of display such as word processor, personal computer, desktop

calculator, liquid crystal television, liquid crystal clock, the demand for a planar illumination device, which can equalize brightness within the surface and produce high brightness, is increasing. To satisfy this demand, a prior art (Japanese unexamined published application No. Sho 64-78283) proposes a planar illumination device shown in Figure 6 and a display panel using said planar illumination device.

[0003]

The above described planar illumination device is comprised of: optical transmission body A, which is made from a plurality of laminated transparent plate-like bodies (a); light source (c), which is positioned in light incidence side (b) of optical transmission body A; and light reflective body (3), which has a specified tilt angle relative to transparent plate-like body (a) and is positioned in light exit side (d) of optical transmission body A. The light beam from light exit side (d) is reflected by light reflective body (e) so that the light beam is converted to diffusion light. Then, said diffusion light is scattered by plate-like light-scattering body (f), which has its surface contacted with optical transmission body A. Consequently, the surface of liquid crystal panel (g) is illuminated.

[0004]

Furthermore, another prior art (Japanese unexamined published application No. Sho 60-87387) proposes a light diffuser shown in Figure 7. According to this light diffuser, optical transmission body B has light incidence end face (h) and light exit end face (i) and is made from a plurality of laminated plate-like bodies (j), which have translucency. At the same time, sloped surfaces (k) of plate-like bodies (j) are continuously arranged so that light exit end face (i) becomes planate and thus light beam (l) of light source (c) enters light diffusion plate (m) from light exit end face (i).

[0005]

[Problems to be Solved by the Invention]

When an optical waveguide device is used for the above described conventional planar illumination devices, however, there are problems described below. For example, in the case of the planar illumination device of Figure 6, to prevent cross talk between transparent plate-like bodies (a), an adhesive agent with a low refractive index or layer of air is placed between laminated transparent plate-like bodies (a) thereby creating optical transmission body A. As a result, light can be independently propagated through each of transparent plate-like bodies (a). By making said

propagated light enter light crystal panel (g) by using light-scattering body (f), the surface can be evenly illuminated.

[0006]

Since the length of each of transparent plate-like bodies (a) is different, however, its propagation loss is different. Therefore, each of the light quantities, which are reflected by light reflective body (e) placed in light exit side (d) of transparent plate-like bodies (a), is also different. As a result, brightness is uneven between the center part and peripheral part of liquid crystal panel (g). Furthermore, among each light, which is reflected by light reflective body (e), the light, which is reflected in the direction vertical to liquid crystal panel (g) (that is, in the case wherein the angle of reflection of the light is about 45 degrees), passes through each of transparent plate-like bodies (a) and said adhesive agent with a low refractive index or layer of air and reaches the surface of liquid crystal panel (g). However, light with angle of reflection much smaller or larger than 45 degrees is reflected or refracted by said adhesive agent with a low refractive index or layer of air and returns to light incidence side (b) and does not reach liquid crystal panel

(g). As a result, brightness of the liquid crystal panel is decreased.

[0007]

In the case of the light diffuser of Figure 7, the length of optical transmission body B, which is made from a plurality of laminated plate-like bodies (j), is also different. Therefore, the light quantities of light exit end face (i) are uneven. This is because the length of optical transmission body B is shorter, the brightness is increased and the length of optical transmission body B is longer, the brightness is decreased. In other words, depending on the difference in length between plate-like bodies (j) of optical transmission body B, the propagation loss is different. Furthermore, it is difficult to make light from light source (c) evenly enter each of plate-like bodies (j). At the same time, since light is independently propagated through each of plate-like bodies (j), it is not possible to equalize the light quantities from each of sloped surfaces (k). Moreover, since light, which is propagated through each of plate-like bodies (j) as described above, is in a confined state, a difference between forwardly scattered light and the backwardly scattered light is larger in light diffusion plate (m) when viewed from the direction of light propagation and the

direction opposite to light propagation. Consequently, it is not possible to prevent uneven illumination, which is affected by said light.

[0008]

The present invention examines the defects of the above described conventional device. As a result, according to the planar illumination optical waveguide device as set forth in claim 1, plate-like optical waveguide layers, which are used as transparent plate-like bodies (a) or plate-like bodies (j) of the above described prior arts, are laminated. According to the present invention, proper phase differences are set between each of the refractive indexes of these plate-like optical waveguide layers. Furthermore, a low refractive index layer with a proper refractive index or high reflectivity layer, on which the above described plate-like optical waveguide layers are laminated, is added. At the same time, light diffusion layer with a properly-selected refractive index is laminated on a light exit end face, which is made from the above described plate-like optical waveguide layers.

/4

As a result, light can not only independently pass through a single plate-like optical waveguide layer, but also interfere with other plate-like optical waveguide layers.

Consequently, it is possible to equalize brightness of the surface and produce high brightness in the surface. The first objective of claim 1 is to obtain the planar illumination optical waveguide device, which can achieve the above described function. In addition, according to the second objective of claim 1, the above described laminated structure is placed in a symmetrical manner and a light source is placed in the middle wherein a space for the light source is created. As a result, it is possible to more effectively obtain uniform and high brightness. At the same time, it is possible to decrease the size of the entire device.

[0009]

According to claim 2 of the present invention, the planar illumination optical waveguide device, as set forth in claim 1, has a minimum relative refractive index difference between the plate-like optical waveguide layers of 1 % or less. As a result, a majority of light with low-order modes are propagated through their own the plate-like optical waveguide layers so as to brightly illuminate the light diffusion layer. Furthermore, light with high-order modes are propagated through other plate-like optical waveguide layers by interfering with them. As a result, it is

possible to achieve uniform brightness in one-layer surface and increase the brightness.

[0010]

According to claim 3 of the present invention, a liquid crystal panel, which is placed on the front surface of the light diffusion layer, is added to the structure as set forth in claim 1. As a result, the device of the present invention can be used for a variety of types of display such as liquid crystal display backlight, liquid crystal television, liquid crystal clock and the like.

[0011]

According to claim 4 of the present invention, in addition to the structure as set forth in claim 1, a light reflective body is placed below said light source. As a result, it is possible to effectively excite light from the light source toward the plate-like optical waveguide layers.

[0012]

According to claim 5 of the present invention, the light incidence end faces, as set forth in claims 1 to 4, of the optical transmission body, which is made from laminated plate-like optical waveguide layers, are properly sloped so that light incidence from the light source is streamlined. Similarly, according to claim 6 of the present invention,

the light incidence end faces are curved so as to increase the light incidence efficiency.

[0013]

According to claim 7 of the present invention, even if the low refractive index layer or high reflective layer, as set forth in claims 1 to 4, is not planar but curved, it is possible to produce the same or better effect. According to claim 8 of the present invention, the thickness of the plate-like optical waveguide layers is not uniform but tapered off. As a result, it is possible to increase interference of the above described light with high-order modes and promote homogenization of light quantities within the light diffusion layer. Moreover, according to claim 9 of the present invention, the plate-like optical waveguide layers with the structure as set forth in claim 10 (translator's note: it should be "claim 1") have hook-like curved shapes, which are made from laterally-facing layer parts and sloped layer parts. As a result, light from the light source can evenly and effectively enter from the light incidence end faces.

[0014]

[Means to Solve the Problems]

To achieve the above described objectives, according to claim 1, the present invention attempts to provide a planar

illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity are obliquely placed in a symmetrical manner so as to create a V-formation; a plurality of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X ($N_1 > N_2 > . . . N_K >> N_L$)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body; end faces of light incidence layers, which are the inner ends of said plate-like optical waveguide layers placed in a symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of said symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit

layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; and a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face.

[0015]

According to claim 2 of the present invention, in addition to the structure as set forth in claim 1, the above described plate-like optical waveguide layers conduct multimode light transmission and the minimum relative refractive index difference $\{\Delta_1 = [(N_K - N_1)/N_K] \times 100\ \%\}$ of said plate-like optical waveguide layers is 1 % or more. According to claim 3 of the present invention, in addition to the structure as set forth in claim 1, a liquid crystal panel is created on the top surface of the above described light diffusion layer. According to claim 4 of the present invention, in addition to the structure as set forth in claim 1, a light reflective body is created below the light source, which is placed in said light source space.

[0016]

According to claim 5 of the present invention, in addition to the structure as set forth in claims 1 to 4, the light

incidence end faces of the optical transmission body are made from a surface, which slopes in the outward direction by a desired angle relative to the perpendicular of the light exit end face. According to claim 6 of the present invention, in addition to the structure as set forth in claims 1 to 4, the light incidence end faces of the optical transmission body are curved and concave to the light source. According to claim 7 of the present invention, in addition to the structure as set forth in claims 1 to 4, the surfaces of the low refractive index layers or high reflectivity layers are flat or curved. According to claim 8 of the present invention, in addition to the structure as set forth in claims 1 to 4, the thickness of the plate-like optical waveguide layers of the optical transmission body is uniform or tapered off along the direction of light propagation.

[0017]

According to claim 9, the present invention attempts to provide a planar illumination optical waveguide device characterized in that: layers with low refractive index N_L or layers with high reflectivity, which are made from horizontal parts and sloped parts connected to said horizontal parts, are obliquely placed in a symmetrical manner so as to create hook-like V-formations; a plurality

of plate-like optical waveguide layers with a refractive index, which is higher than said refractive index N_L and sequentially decreases [N_1, N_2, . . . N_X ($N_1 > N_2 > . . . N_K >> N_L$)], are laminated on said symmetrically-placed low refractive index layers or high reflectivity layers so as to create an optical transmission body and said plate-like optical waveguide layers are made from laterally-facing layer parts and sloped layer parts, which are created together with said horizontal parts and sloped parts of said low refractive index layers or high reflectivity layers; end faces of light incidence layers, which are the inner ends of said laterally-facing layer parts of said plate-like optical waveguide layers placed in a symmetrical manner within said optical transmission body, are continuously arranged from the inner bottom ends of said horizontal parts of said symmetrically-placed low refractive index layers or high reflectivity layers so as to create symmetrically-placed light incidence end faces; a space for a light source and the light source are created between said symmetrically-placed light incidence end faces; end faces of light exit layers, which are the outer ends of said sloped layer parts of said symmetrically-placed plate-like optical waveguide layers, are continuously arranged from the outer top ends of said

sloped parts of said symmetrically-placed low refractive index layers or high reflectivity layers so that said end faces of light exit layers become a flat surface facing upward, connect the top part of said light source space and thus form a light exit end face, which articulates said symmetrically-placed light incidence end faces; and a light diffusion layer with refractive index N_H, which is higher than refractive index N_1 of said plate-like optical waveguide layer, is formed on said light exit end face.

/5

[0018]

[Operation]

According to the planar illumination optical waveguide device as set forth in claim 1, light from the light source enters the first plate-like optical waveguide layer, which is the bottom layer and has refractive index N_1, through the light incidence end face. Then, said light is fully reflected by the second plate-like optical waveguide layer, which is the layer on top of the first plate-like optical waveguide layer and has refractive index N_2 ($N_2 < N_1$), and then reflected by the low refractive index layer with refractive index N_L ($N_L << N_1$) or high reflective layer, which underlies the first plate-like optical waveguide layer. Said reflected light is propagated between the above

described layers and enters the light diffusion layer through the light exit end face thereby illuminating the light incidence part. However, since the length of the second plate-like optical waveguide layer is the longest, the light quantity of said light is relatively small.

[0019]

Said light, which enters from the light source through the light incidence end face of the above described second plate-like optical waveguide layer, is fully reflected by the third plate-like optical waveguide layer, which is the layer on top of the second plate-like optical waveguide layer and has refractive index N_3 ($N_3 < N_2$), and then reflected by the above described low refractive index layer. The reflected light is propagated between the above described layers and enters the light diffusion layer. Consequently, the light incidence part of the light diffusion layer, which corresponds to the light exit end face, is illuminated. At the same time, light from the second plate-like optical waveguide layer also interferes with the first plate-like optical waveguide layer thereby compensating for the light quantity, which is lost in the first plate-like optical waveguide layer.

[0020]

On the other hand, light, which enters the third plate-like optical waveguide layer with refractive index N_3, is fully reflected by the fourth plate-like optical waveguide layer, which is the layer on top of the third plate-like optical waveguide layer and has refractive index N_4 ($N_4 < N_3$), and then reflected by the low refractive index layer and the like. The reflected light is propagated between the above described layers and enters the light diffusion layer. Then, the light compensates for the light quantities, which are lost in the first and second plate-like optical waveguide layers respectively. At the same time, the light illuminates the light incidence part of the light diffusion layer, which corresponds to the light exit end face of the third plate-like optical waveguide layer. Subsequently, the same operation as above is made to the rest of the plate-like optical waveguide layers. Then, a majority of the light entering the plate-like optical waveguide layer, which is laminated on the top and has refractive index N_K, enters the light diffusion layer thereby illuminating the innermost part of the light diffusion layer.

[0021]

In other words, light, which enters a plurality of laminated plate-like optical waveguide layers, is

propagated by interfering with itself. As a result, the problem of small light quantity of the plate-like optical waveguide layer, which is placed at the bottom, is solved. Furthermore, because of the above described compensation, the light quantities from each of the plate-like optical waveguide layers are equalized thereby producing even brightness. Moreover, there is no obstacle, which blocks light while it reaches the light diffusion layer. Therefore, no reflected light is generated toward the light incidence side. In addition, refractive index N_H of the light diffusion layer is higher than refractive index N_1 of the first plate-like optical waveguide layer. As a result, it is possible to obtain the surface with high brightness.

[0022]

Furthermore, since the above described optical transmission body is bilaterally symmetric, only one light source is necessary. Moreover, since the light source is placed inside the space for the light source, which is located at the center part of the optical transmission body, the size of the entire device is small. In addition, it is possible to obtain uniformed brightness throughout the wide surface ranging from the outer part of the light diffusion layer, which is the long plate-like optical waveguide layer

laminated at the bottom wherein light exits, to the center part.

[0023]

According to the planar illumination optical waveguide device as set forth in claim 2, light is transmitted through the plate-like optical waveguide layers based on the multimode light transmission and the minimum relative refractive index difference is $\Delta_1 = [(N_K - N_1)/N_K] \times 100\ \% \geq 1\ \%$. Therefore, a majority of light with low-order modes, which are propagated through each of the plate-like optical waveguide layers, are independently propagated through their own plate-like optical waveguide layers, which contributes to brightly illuminating the light diffusion layer. On the other hand, light with high-order modes is propagated by interfering with other plate-like optical waveguide layers with high refractive indexes rather than its own plate-like optical waveguide layer. As a result, it is possible to compensate for the exiting light quantities, which are different depending on the length of each of the plate-like optical waveguide layers, and illuminate the surface of the light diffusion layer with uniform brightness.

[0024]

According to claim 3, a liquid crystal panel is created on the top surface of the above described light diffusion layer. As a result, it is possible to provide a planar illumination device, which has a desired surface with uniform brightness. According to claim 4, a light reflective body is created below the space for the light source. As a result, light from the light source effectively enters the plate-like optical waveguide layers, which makes it possible to obtain high brightness of the surface and uniformity of the light quantities.

[0025]

According to claims 5 and 6, the light incidence end faces are sloped by a desired angle or curved. As a result, light from the light source effectively enters the light incidence end faces. According to claim 7, even if the surfaces of the low refractive index layers or high reflectivity layers are flat or curved, they have the same or better optical transmission effect. According to claim 8, by making the plate-like optical waveguide layers tapered off, it is possible to increase interference of the above described light with high-order modes and thus promote uniformity of the light quantities within the light diffusion layer.

[0026]

According to claim 9, laterally-facing layer parts are created in the end faces of the light incidence layers of the plate-like optical waveguide layers as set forth in claim 1, and sloped layer parts are slantedly connected to said laterally-facing layer parts. As a result, light can effectively enter the plate-like optical waveguide layers. In addition, the result of the above described light interference is more satisfactory.

[0027]

[Description of the Embodiments]

An embodiment shown in Figure 1 is the so called backlight type planar illumination optical waveguide device, wherein light is transmitted from the center part. The device is bilaterally symmetrical along central axial line X-X and comprised of optical transmission body 1, which has a symmetrical form, light source 2, which is located at the center part, and horizontally-placed light diffusion layer 3, on top of which a variety of types of display panel such as liquid crystal panel 3a is placed. Optical transmission body 1 is comprised of low refractive index layers 4 with refractive index N_L or high reflective layers 4, which is made from a flat surface as shown in the figure or a curved surface, and a plurality of plate-like optical waveguide

layers 5a, 5b, 5c, 5d, 5e and 5f, which are laminated on the surface of said low refractive index layers or high reflective layers. Here, low refractive index layer 4 or high reflective layer 4, which are described above, are formed on the surfaces of base parts 6, which are positioned in a symmetrical manner.

/6

[0028]

Here, according to the present invention, low refractive index layers 4 or high reflectivity layers 4 are obliquely placed in a symmetrical manner so as to create a V-formation. According to the embodiment shown in Figure 1, low refractive index layers 4 or high reflective layers 4 are formed on sloped surfaces 6a, which are the surfaces of base parts 6. Here, as the material for the low refractive index layer, it is possible to use plastics such as teflon, polyvinylidene fluoride, SiO_2, SiO_2 containing at least one type of refractive index controlling additive such as Ti, Ge, P, B, F, Al, Ta, Zr, Zn, Na and K, glass such as pyrex, MgF_2 or ZnS-MgF_2. Importantly, refractive index N_L of the above described low refractive index layer is lower, or preferably much lower than refractive indexes N_1, N_2, . . . N_K of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f. For example, it is preferable that refractive index

N_L is 1.42 to 1.47. In addition, the thickness of the above described low refractive index layer is a tenth of a micrometer or longer.

[0029]

As the material for the above described high reflective layer, it is possible to use a metal film made of Al, Cr or Ag. As the material for base parts 6, it is possible to use metal, plastics and timber and the like. As the material for plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, it is necessary to use a transparent material with good light transmission so that light from light source 2 can be propagated with low loss. Refractive indexes N_1, N_2, . . . N_K of the above described plate-like optical waveguide layers must satisfy the following relationship:

$$N_1 > N_2 > N_3 > N_4 > N_5 > N_K >> N_L$$

In other words, refractive index N_1 of first plate-like optical waveguide layer 5a, which is directly placed on low refractive index layers 4 or high reflective layers 4, is the largest. Then, refractive indexes N_2, N_3, N_4 and N_5 of subsequent plate-like optical waveguide layers 5b, 5c, 5d, 5e and 5f sequentially decrease so that all of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f have refractive indexes higher than N_L.

[0030]

Here, as the material for plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, it is possible to use an organic material such as methyl polymethacrylate (refractive index: 1.49), polymethacrylate with a refractive index controlling additive (refractive index: 1.50 to 1.55) and polyurethane (refractive index: 1.555), photoresist (refractive index: 1.615), a glass material such as CORNING 7059 (refractive index: 1.544) and slide glass (refractive index: 1.512) or an oxide material such as TiO_2, Al_2O_3, SnO_2, GeO_2 and Sb_2O_3. In addition, each of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f may have two or more layers, or preferably, multiple layers. Since the thickness of the laminated layers as a whole is in a range from a few millimeters to a few dozens of millimeters, the thickness of each of the plate-like optical waveguide layers is in a range from 0.1 mm to more than a dozen millimeters.

[0031]

By laminating plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f as described above, end faces 5a', 5b', 5c', 5d', 5e' and 5f' of light incidence layers, which are the inner ends of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, are continuously arranged from the

inner bottom ends of sloped surfaces 6a of symmetrically-placed low refractive index layers 4 or high reflectivity layers 4. As a result, light incidence end faces 7a are symmetrically formed and light source space 8 is created between said light incidence end faces 7a so that light from light source 2 can enter each of end faces 5a′, 5b′, 5c′, 5d′, 5e′ and 5f′ of light incidence layers. In Figure 1, 2a is a light reflective body, which is described in claim 4 and made from a reflector or mirror. By using light reflective body 2a, it is possible to effectively excite light from light source 2 into each of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f.

[0032]

As the material for light source 2, it is possible to use a cold-cathode tube, light-emitting diode array, electroluminescence element or subminiature lamp. More practically, it is possible to use a commercially-available cold-cathode tube with a tube diameter of 6.5 mm, a tube length of about 28 cm and an input power of 8W. Naturally, instead of using a single light source, which is the case of Figure 1, it is possible to use two or more light sources, which can be arranged one above the other or symmetrically. In addition, as the material for light reflective body 2a, it is possible to use a metal material

having its surface coated with a high reflectivity metal material such as Al, Ag and Au, a plastic material or a glass material, or even the above described metals. Light reflective body 2a can be positioned below light source space 8 along base parts 6, which are symmetrically placed. Alternately, light reflective body 2a can be placed in a position as shown in Figures 2 to 5 so that it only closes the bottom part of light source space 8.

[0033]

Furthermore, end faces 5a″, 5b″, 5c″, 5d″, 5e″ and 5f″ of light exit layers, which are the outer ends of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, are continuously arranged from the outer top ends of sloped surfaces 6a of symmetrically-placed low refractive index layers 4 or high reflectivity layers 4 so that said end faces of light exit layers become a flat surface facing upward and connect top part 8a of light source space 8. As a result, light exit end face 7b, which articulates said light incidence end faces 7a, is formed. According to the embodiment shown in Figure 1, light incidence end faces 7a, as set forth in claim 5, slops in the outward direction by desired angle θ relative to light exit end face 7b. As a result, light from light source 2 can effectively enter plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and

5f. Angle θ is preferably 30 degrees or lower. In addition, as shown in Figures 3 and 4, light incidence end faces 7a, as set forth in claim 6, are curved and concave to light source 2. As a result, light from light source 2 can more efficiently enter each of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f. Here, an antireflection film may be coated on light incidence end faces 7a.

[0034]

Light diffusion layer 3 is laminated on light exit end face 7b, which is formed on a flat surface as described above. Here, refractive index N_H of light diffusion layer 3 must be $N_H > N_1$, that is, refractive index N_H must be higher than refractive index N_1, which is the largest of all of the refractive indexes of the plate-like optical waveguide layers. As a result, light exiting from each of end faces 5a″, 5b″, 5c″, 5d″, 5e″ and 5f″ of light exit layers can enter light diffusion layer 3.

/7

[0035]

As the material for light diffusion layer 3, it is possible to use glass, plastics or a chemical compound, which allows light from light source 2 to transmit with good light transmission. Examples of the material include SiO_2, SiO_2 containing at least one type of refractive index

controlling additive such as Ti, Ge, P, B, F, Al, Ta, Zr, Zn, Na and K, glass such as CORNING 7059 (made by Corning Co.) and pyrex glass, plastics such as teflon, polyvinylidene fluoride and polystyrene and a compound such as Al_2O_3, Ta_2O_5, MgF_2 and ZnS-MgF_2.

[0036]

Moreover, a periodic or aperiodic structural change is imposed on the surface of light diffusion layer 3 so that light propagating light diffusion layer 3 reflects diffusely. As a result, the uniformity of brightness within the entire surface of light diffusion layer 3 is further increased. The above described periodic or aperiodic structural change can be achieved by using chemical etching techniques or surface polishing techniques. In addition, a fluorescent material may be contained in light diffusion layer 3 or coated on its surface so as to further increase the brightness. For example, a fluorescent coating material (blue color dye) with a luminescence maximum wavelength of 400 to 700 mm may be mixed into light diffusion layer 3. Furthermore, light diffusion layer 3 has a planar structure, which is shaped in a rectangle, circle or oval, etc.

[0037]

As described above, according to the embodiment as set forth in claim 4, light reflective body 2a is added to the

structure as set forth in claim 1. On the other hand, according to the embodiment as set forth in claim 3, as clearly shown in Figure 1, liquid crystal panel 3a is mounted on the top surface of light diffusion layer 3. As a result, as described above, it is possible to use the device for a variety of types of display such as a liquid crystal television. Here, tilt angle α of sloped surfaces 6a, which are symmetrically formed, is preferably 45 degrees or lower. By decreasing tilt angle α in this manner, it is possible to decrease the thickness of the device and thus achieve a large-size screen.

[0038]

According to the embodiment, as set forth in claim 1, which has the above described structure, light from light source 2 enters light incidence end faces 7a. In the meantime, light, which enters end face 5a' of the light incidence layer of plate-like optical waveguide layer 5a, is propagated by fully reflecting between low refractive index layers 4 or high reflectivity layers 4 with the lowest refractive index N_L) and plate-like optical waveguide layer 5b with refractive index N_2, which is lower than refractive index N_1 of plate-like optical waveguide layer 5a. Then, said light enters light diffusion layer 3 with refractive index N_H, which is higher than refractive index N_1, through

end face 5a″ of the light exit layer thereby illuminating the corresponding part of light diffusion layer 3. Therefore, since the length of plate-like optical waveguide layer 5a, which is laminated on the bottom, is the longest of all, only with the above described light quantity, brightness of light diffusion layer 3, which corresponds to the above described part of light diffusion layer 3, is weak.

[0039]

According to the present invention, however, light, which enters subsequent plate-like optical waveguide layer 5b through end face 5b′ of the light incidence layer, is propagated by fully reflecting between plate-like optical waveguide layer 5c with refractive index N_3, which is higher than the refractive index of plate-like optical waveguide layer 5b, and low refractive index layers 4 or high reflectivity layers 4. Consequently, since said light is also propagated through plate-like optical waveguide layer 5a, light, which exits from end face 5a″ of the light exit layer of plate-like optical waveguide layer 5a, has the above described light quantity plus the light quantity of the above described fully reflected light thereby compensating the light quantities. Naturally, because of light, which exits from end face 5b″ of the light exit

layer of plate-like optical waveguide layer 5b, brightness of the corresponding part of light diffusion layer 3 is also increased.

[0040]

Light, which sequentially enters the subsequent plate-like optical waveguide layers, is propagated through the upper plate-like optical waveguide layers by fully reflecting in the manner described above and compensates for the light quantity lost. In other words, light, which is propagated through each of the plate-like optical waveguide layers, is propagated by interfering with itself. Light, which enters uppermost plate-like optical waveguide layer 5e, mostly enters the light diffusion layer and brightly illuminates the corresponding part. Furthermore, since optical transmission body 1 is symmetrically placed, brightness of the corresponding parts of light diffusion layer 3 is sufficiently increased by light, which enters through the lower plate-like optical waveguide layers, which are symmetrically placed. As a result, it is possible to solve the problems of the prior arts. In addition, light, which exits from optical transmission body 1, does not have the brightness decreasing element of the prior arts nor reflect in the light incidence direction, which is not desired.

[0041]

According to the embodiment as set forth in claim 2, in addition to the structure as set forth in claim 1, the transmission mode of light propagating through plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, is multiple. Here, the minimum relative refractive index difference (Δ_1) is $\Delta_1 = [(N_K - N_1)/N_K] \times 100\ \% \geq 1\ \%$. As a result, light from light source 2 is efficiently confined in the plate-like optical waveguide layers and then propagated. At the same time, a large quantity of light with high-order modes is propagated. In addition to their own plate-like optical waveguide layers, the above described light with high-order modes is propagated by interfering with the other plate-like optical waveguide layers with refractive indexes higher than theirs. Consequently, said light compensates for the light quantity of the exited light based on the difference in length between each of the plate-like optical waveguide layers. As a result, it is possible to maintain the uniformity of brightness within the surface of light diffusion layer 3 and contribute to increase of brightness.

[0042]

The present invention is not limited to the above described embodiments. The cross-sectional surface of base parts 6

does not always have to be triangular. In addition, as long as the state of optical transmission body 1 can be maintained, it is not necessary to create the base parts. Instead, only low refractive index layers or high reflectivity layers may be created below plate-like optical waveguide layer 5a.

[0043]

As described above, according to the embodiment as set forth in claim 5, light incidence end faces 7a are sloped while, according to the embodiment as set forth in claim 6, they are curved. Similarly, according to the embodiment as set forth in claim 7, the surfaces of low refractive index layers 4 or high reflectivity layers 4, as set forth in claims 1 to 4, are curved. As shown in the figure, the above described curved surfaces are convex downward. Consequently, the bottom surfaces of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f are also convex downward. As a result, it is possible to increase the interference of light with high-order modes, which is propagated through each of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, equalize the light quantities within light diffusion layer 3 and decrease uneven brightness.

/8

[0044]

According to the embodiment as set forth in claim 8, as shown in Figure 2, the thickness of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f is tapered off along the direction of light propagation. In other words, when the thickness of light incidence end faces 7a of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f is Wi and the thickness of light exit end face 7b is Wo, Wi > Wo. As a result, it is possible to increase the interference of light with high-order modes, which is propagated through plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f and further equalize the light quantities within light diffusion layer 3.

[0045]

According to the embodiment as set forth in claim 9, as shown in Figure 5, the state of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f is different from that of the embodiment as set forth in claim 1 in the points described below. In other words, low refractive index layers 4 or high reflective layers 4, which are symmetrically placed, are made from horizontal parts 4a and sloped parts 4b so as to create hook-like V-formations. Plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f, which are laminated on top of low refractive index

layers 4 or high reflective layers 4, are made from laterally-facing layer parts 5H and sloped layer parts 5S, which are created together with horizontal parts 4a and sloped parts 4b.

[0046]

In other words, the sides of end faces 5a’, 5b’, 5c’, 5d’, 5e’ and 5f’ of light incidence layers are partially laminated in parallel with the flat surface of light exit end face 7b so that they are sloped upward in the direction of end faces 5a”, 5b”, 5c”, 5d”, 5e” and 5f” of light exit layers. As a result, tilt angle θ can be set smaller than that of the embodiment of Figure 1 and light from light source 2 can efficiently enter each of plate-like optical waveguide layers 5a, 5b, 5c, 5d, 5e and 5f. Since light enters from laterally-facing layer parts 5H to sloped layer parts 5S, the above described light interference, which is induced by full light reflection, occurs. As a result, it is possible to achieve the uniformity of the light quantities within light diffusion layer 3 and decrease uneven brightness.

[0047]

[Effects of the Invention]

Since the present invention has the above described structure, according to the embodiment as set forth in

claim 1, low refractive index layers or high reflective layers, a plurality of plate-like optical waveguide layers and refractive indexes of the light diffusion layer are properly selected so that not only is light propagated through each of the plate-like optical waveguide layers but also interferes with itself. As a result, the light quantity from the long plate-like optical waveguide layer can be supplemented by light from the adjoining plate-like optical waveguide layer and thus brightness within the surface of the display panel can be uniformly maintained. In addition, since, due to the above described light interference, which is induced by the full light reflection, light exiting from each of the plate-like optical waveguide layers enters the light diffusion layer at wider angles, it is possible to solve the conventional problem of the angle dependency wherein brightness of the surface is uneven depending on the viewing direction. Furthermore, since the optical transmission layer does not contain the layers, which cause unnecessary light loss of the conventional example, and unnecessary light reflection in the light incidence direction does not occur, it is possible to provide illumination with high brightness. Moreover, since the device has a symmetrical structure, it is possible to efficiently equalize illumination of a wide surface and

maintain high brightness. In addition, since the light source is placed at the center of the device, it is possible to decrease the size of the entire device.

[0048]

According to the embodiment as set forth in claim 2, since the minimum relative refractive index difference is 1 % or more, it is possible to enhance the light interference as set forth in claim 1 and increase the effect of light quantity compensation. According to the embodiment as set forth in claim 3, since a liquid crystal panel is mounted on the structure as set forth in claim 1, it is possible to provide a product such as a liquid crystal television and liquid crystal clock, which can exert the characteristics of the planar illumination optical waveguide device of claim 1. Furthermore, according to the embodiment as set forth in claim 4, since a light reflective body is added to the structure as set forth in claim 1, it is possible to further increase the above described effects.

[0049]

The embodiments as set forth in claims 5 to 8 are related to the light incidence end faces, low refractive index layers or high reflective layers and plate-like optical waveguide layers of the optical transmission body as set forth in claims 1 to 4. According to the embodiment as set

forth in claim 5, the light incidence end faces are sloped by a desired angle thereby creating a light source space. As a result, light can efficiently enter the light incidence end faces. According to the embodiment as set forth in claim 6, the light incidence end faces are curved and concave to the light source. As a result, it is possible to further increase the efficiency. According to the embodiment as set forth in claim 7, the surfaces of the low refractive index layers or high reflectivity layers are curved. As a result, it is possible to increase the interference of light with high-order modes. According to the embodiment as set forth in claim 8, the plate-like optical waveguide layers are tapered off, it is possible to further increase the interference of light with high-order modes.

[0050]

According to the embodiment as set forth in claim 9, the plate-like optical waveguide layers are made from laterally-facing layer parts and sloped layer parts, which are slantedly connected to each other. As a result, it is possible to increase the light incidence efficiency and light interference.

[Figure 1]

Figure 1 is a schematic front cross-sectional view of the main part of an embodiment illustrating the planar illumination optical waveguide device according to the present invention.

[Figure 2]

Figure 2 is a schematic front cross-sectional view of the main part of another embodiment illustrating the above described device according to the present invention.

[Figure 3]

Figure 3 is a schematic front cross-sectional view of the main part of still another embodiment illustrating the above described device according to the present invention.

[Figure 4]

Figure 4 is a schematic front cross-sectional view of the main part of yet another embodiment illustrating the above described device according to the present invention.

[Figure 5]

Figure 5 is a schematic front cross-sectional view of the main part of still another embodiment illustrating the above described device according to the present invention.

[Figure 6]

Figure 6 is a schematic front cross-sectional view illustrating a conventional planar illumination device and display panel.

[Figure 7]

Figure 7 is a schematic front view of the main part of a conventional light diffuser.

[Explanation of the Codes]

1: optical transmission body

2: light source

2a: light reflective body

3: light diffusion layer

3a: liquid crystal panel

4: low refractive index layer or high reflectivity layer

4a: horizontal part of the low refractive index layer or high reflectivity layer

/9

4b: sloped part of the low refractive index layer or high reflectivity layer

5a: plate-like optical waveguide layer

5b: plate-like optical waveguide layer

5c: plate-like optical waveguide layer

5d: plate-like optical waveguide layer

5e: plate-like optical waveguide layer

5f: plate-like optical waveguide layer

5a’: end face of a light incidence layer

5b’: end face of a light incidence layer

5a”: end face of a light exit layer

5b”: end face of a light exit layer

5H: laterally-facing layer part of a plate-like optical waveguide layer

5S: sloped layer part of a plate-like optical waveguide layer

7a: light incidence end face

7b: light exit end face

8: light source space

8a: top part

N_L: refractive index of the low refractive index layer

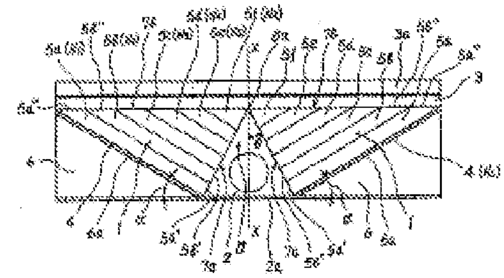
N_1, N_2 . . . N_K: refractive indexes of plate-like optical waveguide layers

N_H: refractive index of the light incidence end face

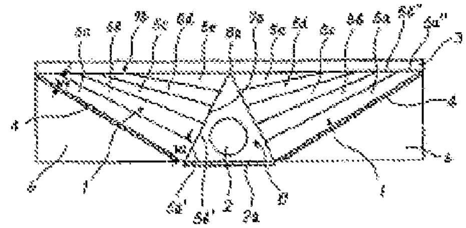
θ: desired angle of the light incidence end face

Δ_1: minimum relative refractive index difference

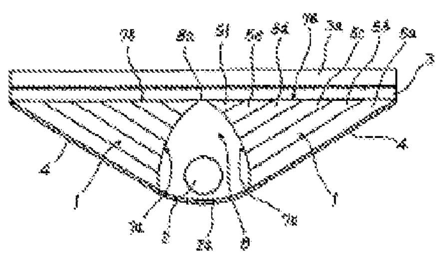
【図1】



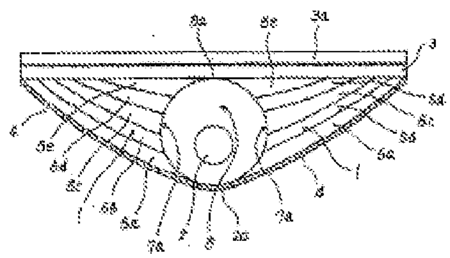
【図2】



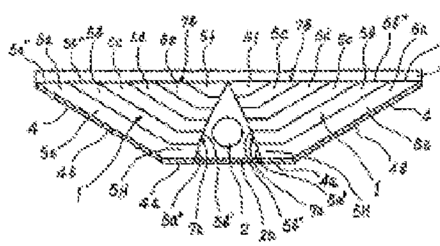
【図3】



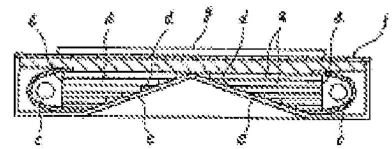
【図4】



【図5】



【図6】



【図7】